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ABSTRACT

Part of the Understanding Our Environment project that is designed to engage students in investigating specific environmental problems through concrete activities and direct experience, this unit uses an in-depth study of a local stream or river to raise questions about the nature, sources, and uses of water. Students begin by identifying the course and uses of a local body of water and building a relief model of the course of water, and conclude with a field study that includes sampling and water quality testing. The objectives are: understanding the role of the water cycle; understanding the importance of water in our lives and the role water plays in supporting all living things; considering the impact of human activities on local waterways, local and global sources of water, and the water cycle; appreciating how people depend on a supply of fresh water; identifying sources and effects of water pollution; creating models of the water cycle, the course of a waterway, and a pond-water environment; collecting and analyzing data on water use and quality; studying and surveying a local waterway to determine its importance to people and other living things and its role in the environment; and acquiring field skills and knowledge students can apply to designing a follow-up cooperative project on water quality. (JRH)

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WATER

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UNDERSTANDING OUR ENVIRONMENT

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WATER

This publication is dedicated to Dr. Alan L. McClelland for his many years of devoted work at DuPont, in the government, and in the community to develop and educate people of all ages in mathematics, engineering, and chemistry. His commitment to advancing the understanding of the sciences has influenced thousands of lives and careers around the world.

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Envelope contents for this unit: U.S. Department of Agriculture, Natural Resources Conservation Service poster: *The Water Cycle, Nature's Recycling System.*
U.S. Geological Survey topographic map.
Save Our Streams (Izaak Walton League) post card.
Transparencies: The Water Cycle.

Cover Photograph: The Student Scientist Water Quality Project by Kelly Lane, science teacher, Douglas Middle School, EAFB, South Dakota.

***Patricia Rourke, Chairperson of the Science Department for grades 7–12 at The Potomac School in McLean, Virginia, helped to edit the original DuPont publication* Understanding Our Environment.**

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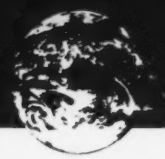

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Discuss the role and importance of the water cycle, the processes involved, and related topics. Create a diagram and two working models of the water cycle.

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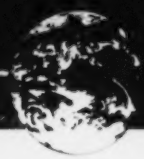


Water, Water, Everywhere, but Is It Safe for Life?

An in-depth study of a local stream or river provides the focus for raising questions about the nature, sources, and uses of water and culminates in an investigation of water quality. Students build a model of the water cycle, learn about sources of fresh water, and research the use of water in their homes. The project begins with students identifying the course and uses of a local body of water and building a relief model of the course of water through the local pond or stream, from the source to the ocean or other destination. Students conclude the project with a field study that includes sampling and water quality testing or, alternatively, with a similar but less ambitious classroom-based study. These investigations lead students to an understanding of the centrality of water in the environment and in their lives.

Objectives

- Understand the role of the water cycle in distributing water on Earth and providing sources of fresh water.
- Understand the importance of water in all aspects of our lives and the role water plays in supporting all living things.
- Consider the impact of human activities on local waterways, local and global sources of water, and the water cycle.
- Appreciate how people depend on a supply of fresh water.
- Identify sources and effects of water pollution.
- Create models of the water cycle, the course of a waterway, and a pond-water environment.
- Collect and analyze data on water use and quality.
- Study and survey a local waterway to determine its importance to people and other living things and its role in the environment.
- Acquire field skills and knowledge students can apply to designing a follow-up cooperative project on water quality.

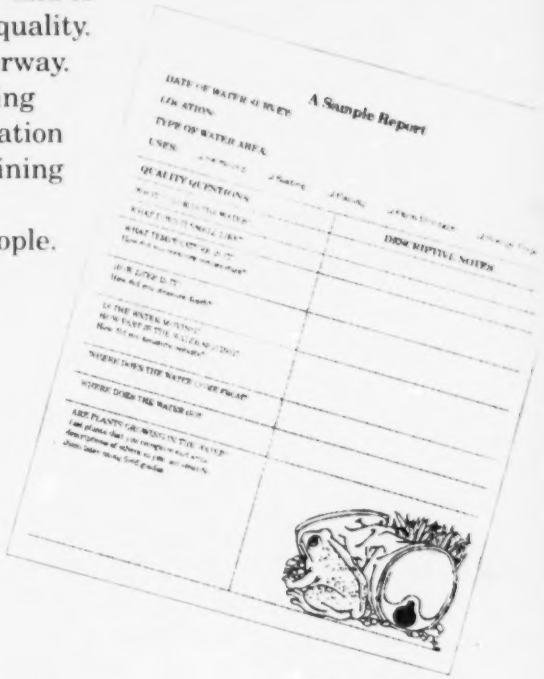
Project Description

Students prepare for the project by studying the water cycle and its role in the distribution of water on Earth. A survey of their domestic water use leads students to appreciate how much they depend on a supply of fresh water and to understand the effect of their activities on water quality.

The three-part project is a study of a local waterway. In Part I students begin their research by gathering information on the course of the waterway, its relation to other waterways, its natural features and adjoining landscape, the ecology along its course, and its historical and current use and modification by people. Students make charts to show their findings.

In Part II, students make a physical model of the waterway.

Field research constitutes Part III. Students learn to collect data, keep field journals, and perform tests for water quality to assess the condition of the waterway. They also learn to present their findings as a group. If field research is not possible, the mini-pond study is an alternative, or teachers may design another classroom activity that reflects available resources.



Water quality report

Using skills learned in this unit, students may want to pursue a follow-up, cooperative community project that focuses on clean water and preserving the environment. A report on the restoration of the Runnins River—an award-winning, two-year effort by four students that identified a local problem and worked out a practical solution—illustrates such a project. If time permits, conclude with "The Clean Water Challenge," a role-play activity in which students form groups to simulate a public inquiry into the contamination of a river. (See Challenge unit.)

CLEAR	the print is easy to read
SLIGHTLY CLOUDY	the print is fuzzy
CLOUDY	the print can be seen but not read
VERY CLOUDY	the print can barely be seen
OPAQUE	the print cannot be seen

Water clarity card

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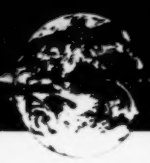


The Water Cycle

Use the following introductory activity to help students discover what they personally "know" about water and as a lead-in to a discussion of the water cycle.

Discussion: Water and the Senses

Students should work in groups of three to brainstorm about water and the senses, then record their responses to the following questions: What do our senses tell us about water? How does water sound, smell, and taste? What does it feel like? What does it look like? The students should then compare their responses.

You may also ask students, "How do you know about the water in your lives? Where does it come from?" Keep the discussion on a personal level, so students draw from their own experiences to discover relationships relevant to the water cycle.

Suggested Resource

The National Public Radio program "Water: Thirsting for Tomorrow," which aired on November 13, 1993, as part of the National Geographic Society's major Fresh Water Initiative may provide a stimulating point of departure for the discussion groups.

NPR has an Educator's Guide to "Water: Thirsting for Tomorrow," which includes an audiocassette of the program, background information, classroom activities, discussion starters, and a resource list. It is available for $35, payable to National Public Radio Outreach, 635 Massachusetts Avenue NW, Washington, DC 20001.

Information Sheets: Nature's Recycling System

The Information Sheets that begin on page 13 provide introductory readings on a variety of subjects related to the water cycle and the distribution of water on Earth. You may choose to photocopy and distribute them to students before or after the activities that follow. You may either distribute all 10 pages or use the first five for the water cycle activities and the last five for the activities on water use in the next section.

Discussion and Activity: The Water Cycle

Distribute the Information Sheets before or after a class discussion on the water cycle. Or you may prefer to have students make models of the water cycle (see pages 10 and 11) before you present any text or diagrams.

Use the color transparency of the water cycle on the overhead during the class discussion. Distribute the Activity Sheet "The Water Cycle" and ask students to label the diagram as indicated.

You could include in the discussion: groundwater, aquifers, artesian wells, capillarity, and salt-water intrusion. Students may write their thoughts on what becomes of precipitation as it runs off or percolates through soil and rock to accumulate as groundwater. Ask students to sketch aquifers and trace the water's path. Ask if they think aquifers can be polluted by (a) human use of water, (b) commercial and recreational use of land next to water, or (c) atmospheric pollution.

Students could describe the water cycle in their own words. Begin focusing their thoughts on environmental consequences by requesting they write paragraphs on how pollution affects water as it passes through the water cycle and how their water use affects the environment and water as it passes through the water cycle.

Aquifers provide water for wells.

Activity: Modeling the Water Cycle

Students may build models of the water cycle as class or home projects, or you may demonstrate with the models. (See Activity Sheets "The Water Cycle: Model A" and "The Water Cycle: Model B.") If you use both models, you may then wish to ask students why they used ice in Model A and the Sun in Model B.

Follow this activity with small-group discussions of why the ocean is salty. (Hint: River water contains a tiny amount of dissolved salts, which it picks up from the land.) Students may also research stories and legends about the origin of salt in the ocean.

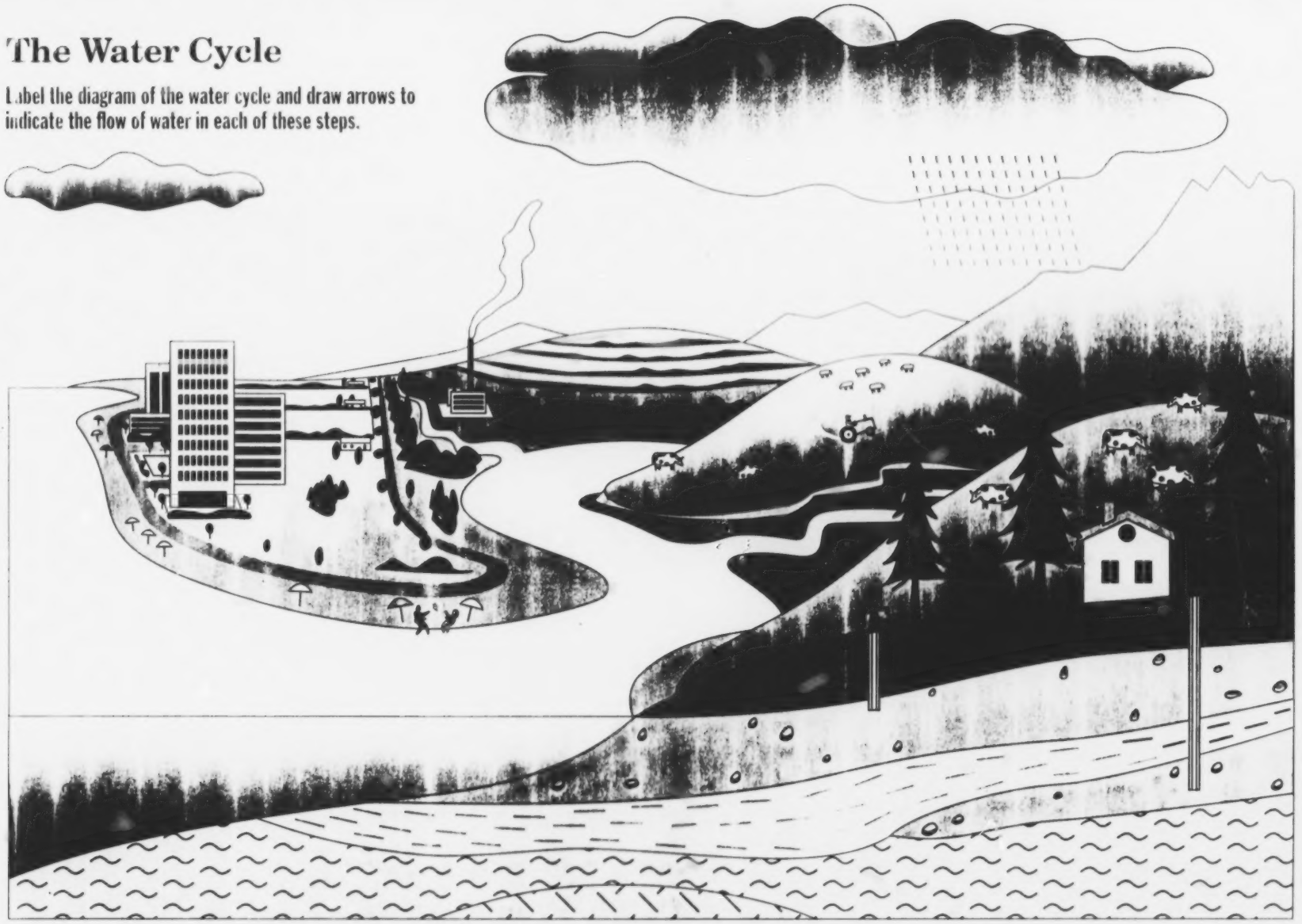
Extension: Electrolysis of Water

You may wish to include the activity "The Composition of Water" (page 49) to clarify the difference between the physical changes involved in the water cycle and chemical changes that occur in polluted water.

Rivers carry small amounts of salt into the ocean.

The Water Cycle

Label the diagram of the water cycle and draw arrows to indicate the flow of water in each of these steps.



1. Water falls to Earth in some form of precipitation (rain, hail, snow, fog, dew).
2. The precipitation replenishes the water in streams, rivers, ponds, and lakes.
3. Some of the water seeps into the ground.
4. Plants and animals take in water.
5. Plants and animals give off water.
6. Water vapor forms as water (soil moisture) evaporates from the ground.
7. Water vapor forms as surface water from ocean, rivers, and lakes evaporates.
8. Water condenses in the atmosphere.

The Water Cycle: Model A

Some parts of the water cycle are evident. You can observe rain falling to Earth, and you may have seen water flow from a stream into a bay or the ocean. It is more difficult to observe evaporation and condensation. To investigate these processes, you will build physical models similar to the two below.

Materials

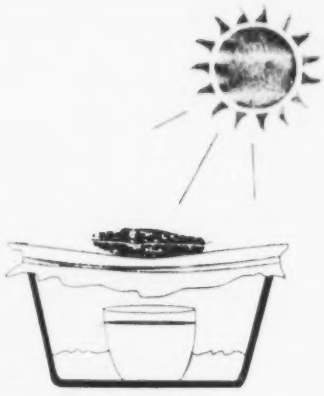
- Kosher salt or table salt
- Hot, but not boiling, water
- Heavy-duty leaf bag, cut open to form a plastic drape
- Spoon
- Ice cubes
- 2-liter plastic soda bottle, cut in half lengthwise
- 1-liter plastic soda bottle with a small opening cut in its long side so ice may be placed inside
- Several smooth blocks of wood or laboratory stands to support the larger soda bottle, which will be placed at a slight slant
- 2 small glass, plastic, or china bowls

Water Cycle, Model A

Procedure

1. Place several tablespoons of salt in the larger bowl. Add a little tap water to dissolve the salt, and stir with the spoon. Set this saltwater aside.
2. Set up the supports, halved plastic bottle, and plastic drape as shown in the diagram of Model A.
3. Make sure the soda bottle is at a tilt, and carefully arrange the plastic so it hangs over the smaller bowl.
4. Place the 1-liter bottle inside the 2-liter one.
5. Add ice cubes to the 1-liter bottle. Do this carefully, so that no water drips on the model.
6. Add hot water to the dissolved salt in the larger bowl, and gently push the bowl under the 2-liter container.
7. Watch the model during a class period.
8. Mark the diagram of Model A to indicate what you see happening.
9. Describe what you observe and what is happening.
10. Taste the water you have collected in the smaller bowl. Is it salty?

The Water Cycle: Model B



Water Cycle Model B

Materials

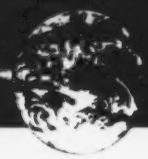
- A large bowl, preferably clear
- A smaller bowl or cup
- A piece of plastic from a heavy-duty trash bag
- A small bag of rice or beans to use as a weight
- Large rubber bands that will fit around the rim of the larger bowl
- Kosher salt or table salt
- A spoon
- Hot, but not boiling, water

Procedure

1. Place several tablespoons of salt in the large bowl. Add a little tap water to dissolve the salt and stir with the spoon.
2. Set the smaller bowl or cup in the center of the large bowl.
3. Carefully add hot water to the large bowl until the liquid reaches halfway up the outside of the small bowl.
4. Gently cover the large bowl with the plastic. Fasten the plastic tightly with a rubber band.
5. Place the container in a warm sunny spot.
6. Place the weight in the center of the plastic cover.
7. Allow this setup to stand undisturbed for several hours.
8. Carefully remove the plastic cover and check the cup or small bowl. Has anything happened?
9. Mark the diagram of Model B to indicate what has happened.
10. Write a brief description of what you have observed and explain what you think has happened.
11. Taste the liquid in the cup or small bowl. Is it salty?

Question

Can you think of a way that drinking water is made from salt water in places where there is a plentiful supply of salt water, little drinking water, and a great deal of sunshine?



Nature's Recycling System

Today, people appreciate how important it is to recycle materials. Metal cans, glass bottles, plastics, newspaper, and paper are high on the list. Bins for many of these things are kept in supermarket parking lots and other places. Many schools separate recyclables from other trash.

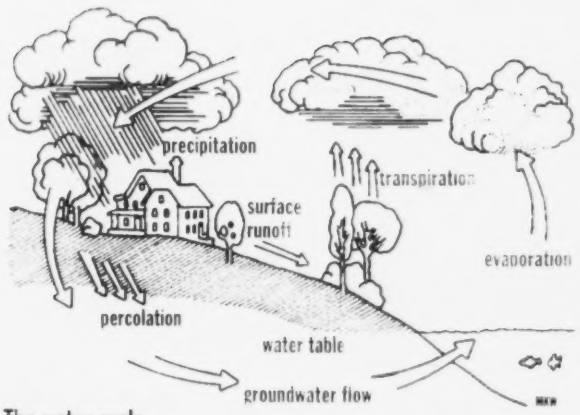
But what about water? Is it recyclable? How do we deal with this precious resource?

Where are the recycling bins for used water? The natural environment we live in is a huge recycling system for water. We call this system the water cycle. Without the water cycle there would be no life on land.

Observing the Water Cycle

How do you know about the water cycle? All of you have seen and felt water falling from clouds in the sky. Once precipitation reaches the land surface, some soaks into the ground. Some of that water is then taken in through the roots of plants growing in the soil, and some sinks deeper into the ground. Where precipitation falls on rocky ground, much flows over the land to streams, rivers, and lakes. Eventually, most water that falls as precipitation finds its way to Earth's oceans.

Eleven major river systems in the United States discharge, or should discharge, substantial amounts of water into the oceans, or the seas, bays, and gulfs. Much of the flow of many western rivers, including the Sacramento, Columbia, Colorado, and Missouri, is diverted for irrigation. Almost no Colorado River water actually enters the Gulf of California. Southwestern rivers like the Rio Grande are not shown because they drain large areas but have relatively small discharge volumes. Large volumes of water from eastern rivers, particularly the Delaware, Hudson, and Susquehanna, are diverted for drinking water.



The water cycle

Major U.S. Rivers with Large* Ocean Discharge

(from east to west)

1. Saint Lawrence River
2. Hudson River
3. Delaware River
4. Susquehanna River
5. Apalachicola River
6. Mobile River
7. Mississippi-Missouri river system
8. Colorado River
9. Sacramento River
10. Columbia River
11. Yukon River

* If not diverted.

Sources: *Large Rivers of the United States*, Geological Survey Circular 686, Water Resources Division, U.S. Geological Survey, Washington, D.C., 1974; Largest Rivers in the United States, Water Resources Division Fact Sheet, U.S. Geological Survey, 1990.

What happens to the trillions of liters of water that fall on the United States on an average day? Usually, about 3 percent will seep underground and about 31 percent will run off to rivers, streams, and lakes. This may be the most familiar part of the water cycle.

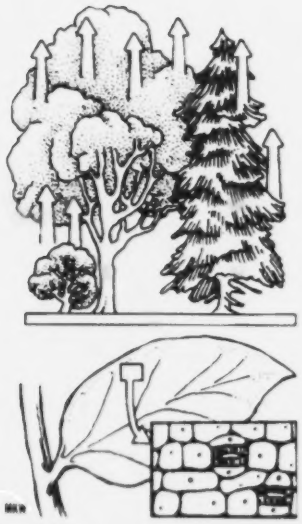
Rain or snow falls on the ground and runs into streams or seeps into soil.

What Happens to the Rest of the Water?

The remaining 66 percent of the water returns to the atmosphere through evaporation and transpiration.

If you put some water in a glass and leave it on a sunny window sill for a few days, you will see that the water level in the glass drops as time passes. As the water in the glass absorbs the energy from the Sun, some of it changes physical state from liquid to gas. Water as a gas is called **water vapor**. Water molecules escape from the surface of the liquid water in the glass to mix with the air. The process of change of physical state from water as a liquid to water as vapor is called **evaporation**.

Plants take water from the soil through their roots. They release water vapor to the atmosphere through thousands of small holes (called stomata) on the backs of their leaves, in a process called **transpiration**. A big oak tree gives off about 150,000 liters of water a year. Transpiration can put more water vapor in the air than evaporation from soil, lakes, and streams.



In transpiration, plants release water vapor through their stomata. The small openings on the underside of plant leaves are called stomata.

Solar energy warms the surface of the land and rivers, causing ice to melt and water to evaporate. Most importantly, water at the vast surface of Earth's oceans absorbs solar energy and evaporates.

Where Does the Evaporated Water Go?

Consider what happens as water evaporates from the ocean. Water molecules absorb solar energy and move from the ocean surface into the air, becoming vapor. The air above the ocean also warms and rises, starting a convection cell and carrying water vapor with it.

As the warm air goes higher, it cools. When the cooling water vapor settles on sea-salt crystals, dust, or other particles in the air, it turns back to liquid, as tiny droplets of water. The change from water vapor to liquid water is called **condensation.** The particles carrying the droplets are so small and light, they can drift in the air.

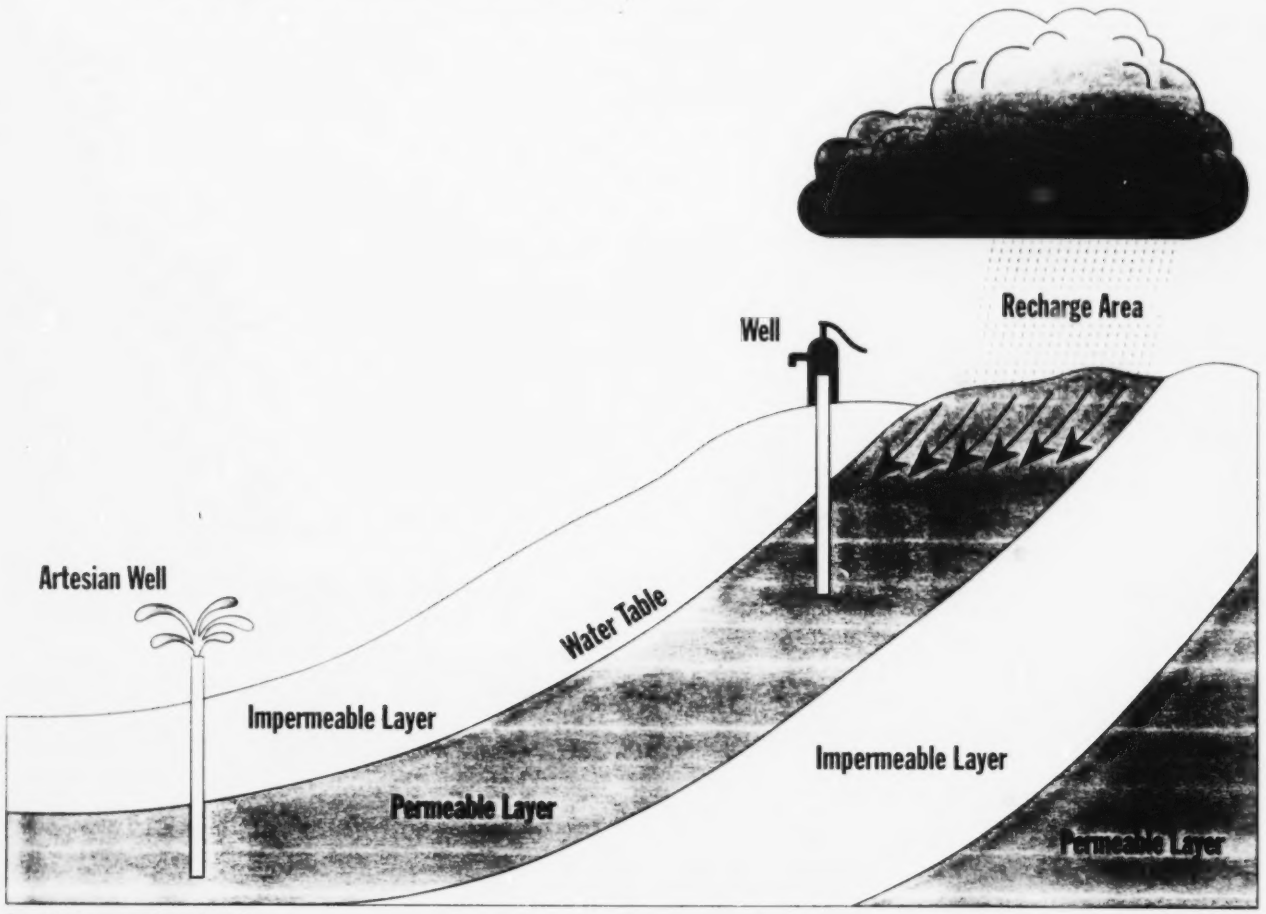
We now see how water moves at Earth's surface. Water that falls from clouds to the ground as precipitation and travels down rivers to the ocean moves from the ocean back into the air. Water vapor condenses to droplets and forms clouds when pressures and temperatures in an air mass

are right. The droplets may begin to join together and make larger drops. If they become too large, they cannot stay in the air any longer. It will rain, or snow, or hail again.

What Happens to Water in the Ground?

Water is held underground in permeable layers of sediment and rock.

When water enters the ground, it passes through spaces between soil and rock particles and cracks in the rocks. Some water is taken up by plant roots. Water in the ground seeps downward until it is stopped by an impermeable layer of clay or rock. Groundwater accumulates above such a layer. The layers of sediment and rock in which groundwater is stored are called **aquifers**.



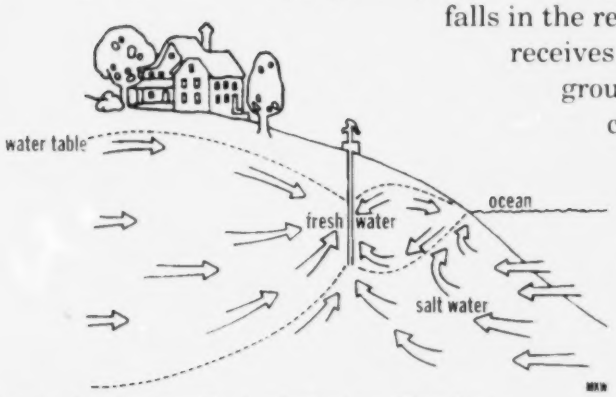
Groundwater moves through aquifers.

As water seeps into and through an aquifer, much organic material and fine sediment carried by the water are removed. In the zone where plenty of air is in the soil, decomposers remove the organic material. The sediment is trapped in the small spaces through which water can pass. In this way, the aquifer is a natural filter. Some groundwater is drinkable without needing treatment. Some bottled water that you buy in stores comes from aquifers.

Water in an aquifer flows downhill, just as surface water does. Water enters an aquifer in the **recharge area** and flows out of it in the **discharge area**, at a spring, swamp, or river. An aquifer discharges at an elevation lower than where it is recharged. Water flows downhill through an aquifer by gravity.

In an **unconfined aquifer**, water seeps down through soil and rock until it meets an impermeable layer, then moves downhill above that layer. Water in a **confined aquifer** moves between two impermeable layers. It is under pressure produced by the weight of water at the higher end of the aquifer.

In some aquifers groundwater may travel hundreds of miles from the recharge to the discharge area. Because people may deplete an aquifer by using more water than falls in the recharge area—particularly if it receives limited precipitation—groundwater cannot always be considered a renewable resource.



Salty ocean water enters an aquifer where fresh water can't keep it out.

Aquifers can be contaminated. Agricultural and industrial waste, including organic chemicals like solvents, fertilizers and pesticides, liquid fuels, dissolved metal compounds, brines, and detergents, is entering groundwater in increasing quantities, making some water unfit for drinking. Aquifers near the ocean experience intrusions of salt water when people use fresh water faster than it travels through the aquifer and seawater is forced in.

What Is the Water Table?

When water soaks into the ground, it fills available space. The region where groundwater fills all of the pores and spaces is called the **zone of saturation**. Between the land surface and the zone of saturation, the pores and openings in the rock and soil are filled partly by air and partly by water. This region is called the **zone of aeration** (or unsaturated zone).

The boundary between the two zones is called the **water table**. Unlike the surface of a lake or pond, the water table is not flat. The elevation of the water table rises and falls about the same way the land surface does.

Wherever you see naturally occurring water—springs, ponds, lakes, steams, rivers—you are seeing the water table intersecting the land surface. Natural springs are the sources of many rivers and streams.

Part of the water cycle.

INFORMATION SHEET : WATER
NATURE'S RECYCLING SYSTEM

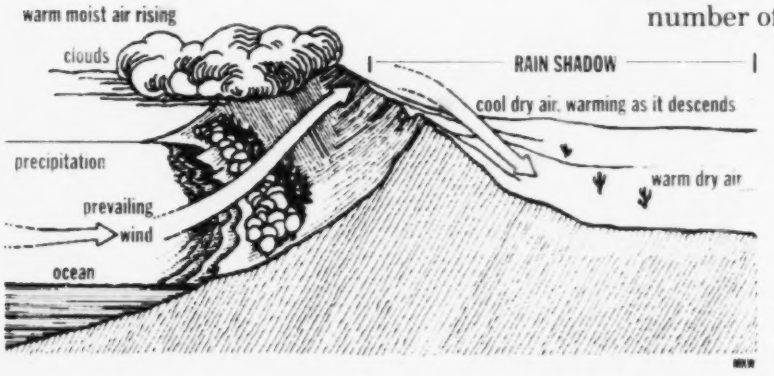
How Much Fresh Water Is There?

Of all the water in the world, more than 97 percent is in the ocean and is salty. Of all the nonocean water (the other 3 percent), 75 percent is frozen in ice caps and glaciers (fresh water), 24 percent is groundwater (some of it salty), 0.6 percent is moisture in the soil (fresh), and 0.4 percent is in inland seas, rivers, and in freshwater and saltwater lakes. Of all the fresh, surface water in the world, about 25 percent is in the Great Lakes system in the United States and about 20 percent is in Lake Baikal in Russia.

For our regular water supplies we rely primarily on precipitation that runs off the surface into lakes and rivers, together with a smaller amount of accessible groundwater. The ocean is the ultimate source of virtually all of our fresh water supplies, as a result of its role in the water cycle.

Where Is the Water?

Water is not evenly distributed across the world. There are wet climates and dry climates. The amount of water available to people depends on where they live, the time of year in some regions, and the number of people living there and how much water they use.



Areas with good supplies of water are those where rainfall is adequate and regular and where evaporation does not occur too quickly. Many parts of the United States have more than adequate rainfall. The northwest coast of Hawaii is one of the wettest places on Earth. In contrast, low rates of precipitation or high temperatures or both produce arid conditions, as in the southwestern parts of the United States.

Big differences exist even within states. As winds blow moist air over a mountain range, precipitation occurs on the windward side, while the other side of the mountain, the leeward side, may remain dry. In the state of Washington,

for example, the west side of many mountains receives plenty of rain and snow, while the east side, in the "rain shadow," is a desert.

The seasons have a strong effect on water supplies in parts of North America. In some of the western states, periods of drought are followed by bursts of heavy rain. Many areas flood because huge volumes of water cannot be stored for use during drier periods. Parts of southern California experience frequent floods during the area's rainy season, and city planners have accommodated the rapid rise of water during severe storms by building debris basins, storm drains, and specially designed flood channels to keep water away from densely populated areas. Large amounts of water are deposited in summer and fall by hurricanes on coastal areas of North and South Carolina, Georgia, Florida, and the other East and Gulf coast states. Some places are inundated with water from rivers swollen to overflowing by snow and ice melting with the onset of warmer spring weather. Parts of nine states in the upper Mississippi and lower Missouri river basins were severely flooded in 1993 after a record spring and summer rainfall.

Is There Enough Water for Everyone?

At present, millions of people suffer from severe water shortages, and the problem is getting worse as populations increase and agriculture and industry develop. It has been estimated that between 30 and 80 countries will suffer serious water shortages by the end of this century. In the Middle East, for example, several countries on the Persian Gulf already rely on desalination plants—factories that make fresh water from salt water—and imported water.

What Affects the Quality of the Fresh Water We Use?

Water quality, as well as supply, is a matter for concern. People need a plentiful supply of clean water and safe disposal of wastewater.

Because rivers, streams, and lakes are frequently expected to serve both purposes, water quality can deteriorate rapidly. Water is considered polluted when municipal, industrial, or natural waste is present in such

quantities that natural processes cannot maintain water quality.

The main kinds of pollutants of fresh water and some of their consequences are identified in the table below.

Major Pollutants of Fresh Water

CAUSE OF POLLUTION	CONSEQUENCES OF POLLUTION
Organic Matter • Sewage from towns and cities. • Slurry from farm.	Increased levels of nitrates and phosphates cause growth of algae and bacteria, which use up the dissolved oxygen in the water, which fish need for survival.
Sediments • Natural erosion of hills and river banks. • Waste products from mines, construction areas, and farms.	Silting up of rivers and streams, which become slow-moving and thus fertile breeding grounds for disease-carrying organisms. Burying of river and lake beds in deep layers of sediment, some of which is contaminated with toxic material.
Toxic Waste • Metals, petrochemical products, solvents, heavy metals, and minerals from industrial areas. • Some organic industrial waste. • Storm water containing household detergents.	Poisoning of fish and other water organisms. Illness in humans.
Farm and Garden Chemicals • Fertilizers and pesticides used on farms, in gardens, on golf courses, and in parks.	Build-up of pesticides in organisms, which become more concentrated in the bodies of animals near the top of the food chain, such as large fish, otters, birds, and humans.
Disease-Carrying Organisms • Bacteria found in sewage build up rapidly in slow-moving and still water such as ponds, ditches, and lakes. • Mosquitoes, which breed in still water.	Illness in humans caused by bacteria. Spread of diseases like malaria by mosquitoes.

Seawater Quality

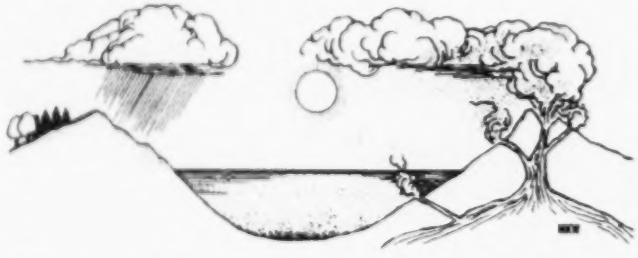
The water that falls to Earth is not really pure. What we call fresh water contains suspended solid particles and dissolved gases from the atmosphere, dissolved organic compounds from soil, and dissolved minerals, called salts, from rocks.

Seawater contains dissolved salts in great quantity, including sodium chloride, magnesium chloride, magnesium sulfate, and potassium chloride. Seawater tastes too salty to drink, and drinking it would harm your body because the salt would absorb water from your cells. So seawater cannot be used for drinking unless it is desalinated.

Water is sometimes called the universal solvent, because many compounds dissolve in it. The ability of water to be a good solvent has its disadvantages. Substances that dissolve in water can also pollute it. Some of those substances end up in Earth's oceans and its seas, straits, bays, and gulfs.

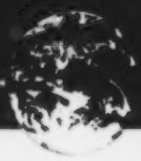
Much of the waste produced by humans ends up in the ocean. Some of it is dumped there but most of it is washed off the land and into the ocean by rain and rivers. An example is the phosphorus used for fertilizer.

Phosphates used in fertilizers are absorbed by the plants in the soil. Animals such as cattle eat the plants. Some of the phosphate fertilizer washes off the land into streams and rivers, and the animal wastes decompose and wash into the water. People eat beef from the cattle and more of the phosphate ends up in human wastes. Sewage systems rarely remove phosphates, and water-quality problems in rivers and lakes result. The water from most of these rivers and lakes eventually makes its way to the ocean.



Evaporation concentrates salts in water.

Accumulations of dissolved salts and suspended solids washed in by rivers do not completely explain why the ocean, or sea, is salty. The salts in seawater become more concentrated because solar energy vaporizes water from the surface as part of the water cycle. As the water evaporates, it is pure and leaves behind the salts and impurities.



Sources of Waste in the Ocean

Human activity on land causes most marine pollution, and most of this pollution remains in coastal waters.

The following are the major sources of pollution of the world's ocean:

- Polluted water from rivers, sewers, and outflows from industry
- Pollutants in the atmosphere
- Discharge from ships, including oil spills
- Sewage sludge and waste dumped at sea

In recent times the amount and variety of waste entering the ocean has increased rapidly. When waste becomes concentrated, it poses a threat to human health and to ocean life. We need to find out more about the ability of the ocean to absorb waste and to determine ways to control waste production and disposal.

The table below identifies some effects of the wastes found in the ocean.

Major Pollutants of Seawater

Oil Spills and Dumping	Oil pollution damages and kills wildlife. Some substances in oil may cause cancer. Poisonous substances in oil sometimes persist in the ocean for long periods.
Sewage	Untreated sewage contains harmful bacteria and viruses. Swimming in water polluted with untreated sewage can cause eye, ear, and skin infections and stomach illness.
Trash	Plastic debris persists for long periods. Marine fish, birds, and mammals can be strangled by plastic line and net, and choked by plastic items that look like food.
Toxic Industrial Waste	Toxic metals such as mercury can cause death in humans who eat contaminated fish or seafood.
Farm Chemicals	Nitrates and phosphates, which cause algal blooms that consume massive quantities of oxygen, wash into water. Water organisms need oxygen to survive. Some pesticides are toxic to humans and animals and are slow to degrade.
Radioactive Waste	The effect on sea life and humans is not known. High levels of radiation have been found coming from corroding containers of waste dumped in deep water.

Water Use and Quality

The Information Sheets on water distribution and quality (pages 18–22) may be photocopied for classroom distribution.

Activity: How Much Water Do You Use?

Students investigate their personal water use and consider the effect of domestic water use on water supply and water quality.

The following estimated water-use information may be helpful:

1. The average volume of water used per person per day in the United States is 325 liters. (1 gallon = 3.78 liters.)
2. Experts estimate that 40% of domestic water use in the United States is for flushing.

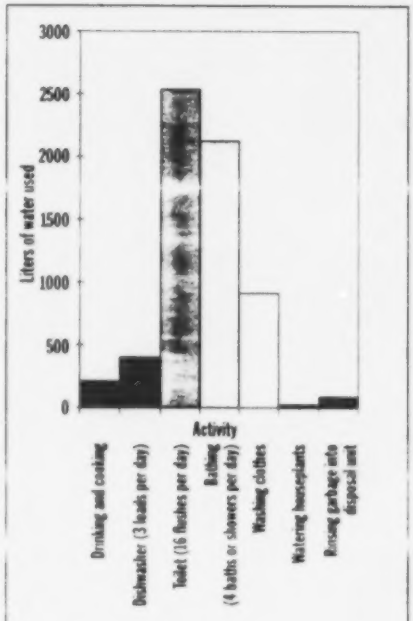
Some guidelines for common activities:

ACTIVITY	ESTIMATED VOLUME
Taking a shower	190 L (50 gal)
Taking a bath	114 L (30 gal)
Washing dishes by hand	38-114 L (10-30 gal)
Washing dishes by machine (per load)	38 L (10 gal)
Washing clothes by machine (per large load)	228 L (60 gal)
Flushing the toilet (per flush)	22.8 L (6 gal)

(Reminder: In liquid measure, 1 gallon = 3.78 L, 1L = 0.26 gallon)

Source: *Environmental Science Activities Kit*, Michael L. Roa, West Nyack, NY: Center for Applied Research in Education, 1993, p. 114.

Selected answers to
"Industrial and Agricultural Use" in "How Much Water Do You Use?"
In the United States, on average, factories use water 2.2 times before it is discarded. Water used by agriculture can be saved by making irrigation systems more efficient.



Adapted from *Earth: The Water Planet*, by Jack E. Gartrell, Jr., Jane Crowder, and Jeffrey C. Callister, Washington, DC, National Science Teachers Association, 1989, p. 85.

Suggested Resource

To purchase useful materials on water quality, pollution, and use, contact the Water Environment Federation, 601 Wythe Street, Alexandria, VA 22314-1994.
Telephone: 703-684-2400 or 1-800-666-0206.

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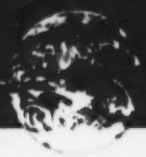


Extensions

1. Students may investigate where the local water supply comes from and write a report on their findings. They may also visit the local wastewater treatment plant or water delivery facility.
2. Have students find out how much water is saved by different actions, such as fixing leaking faucets, taking a quick shower instead of a bath or long shower, turning off the water while brushing teeth, using full instead of partial loads in washing machines and dishwashers, installing water-saving toilets and shower heads, and washing cars less often. Ask students to think of other ways to conserve water.
3. You may wish to encourage a tasting of water samples as a small-group or independent activity. Include spring water, bottled mineral water, distilled water, boiled tap water, and local water, if available.

Activity: Filtering Water

This activity may be done as a demonstration, a student activity, or a homework project. You may wish to start with a preliminary discussion:

1. How many liters of water do you need each day to survive? What does this amount of water look like? (Measure it into a container.)
2. In some European countries people use an estimated 80 liters of fresh water per person per day to stay clean and healthy, although a person can exist on about 4 liters, or about a gallon, per day for the most basic existence. What do 80 liters of water look like? What would an 80-liter container look like? Do you think you use more or less than this amount?
3. Discuss the problems of providing clean water for drinking. Ask why this could be an expensive process.
4. Ask students to consider why more and more people are buying bottled water and to compare the costs of a liter of bottled water and a liter of tap water.

Resources

Gartrell, Jack E., Jr., Crowder, Jane, and Callister, Jeffrey C. (1989). *Earth: The Water Planet*. Washington, DC: National Science Teachers Association.

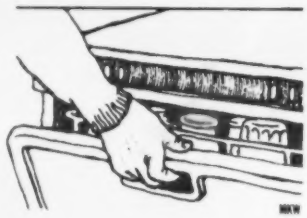
How Much Water Do You Use?

In this activity, you will estimate how much water you use to stay clean and healthy for a day. You will also figure out how much water you and your family use at home each week.

Gathering Data on Water Use

Start by making a list of all household fixtures and appliances that use water. Then begin a detailed record of all the water you use on a daily basis. Because water use varies from day to day, you should imagine a typical day.

Your Survey. Make a data chart similar to the one on the next page. Try to list all the ordinary activities for which you use water. Include any bottled water and other drinks that you buy. Think about how you use water for recreation.

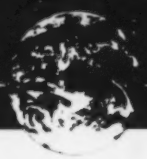


Estimation. To determine the volume of water used for each activity, you may need to use some estimation strategies. Devise ways to measure water use as accurately as possible, using measuring cups and milk or soda containers. Look for manufacturer's manuals and other sources that may help you estimate the amount of water used by home appliances.

Finding ways to measure household water flow is an interesting challenge. Be sure to keep notes on your methods and on the sources of information you use.

Family Use. Once you have recorded the data for your daily water use, consider what additional water your family uses during the week—for example, to wash clothes, to wash the kitchen floor, to give the dog a bath, or to water the garden. Add these activities to the chart and estimate the amount of water your family uses for these non-daily activities in
one week.

The Total. Finally, compute the total amount of water you and your family use in a week for personal hygiene and to keep your home in its usual state. Then draw a bar graph similar to this one to show what you have found. Reminder: Record your data in liters, not gallons.



Personal Water Use Survey

Name:

Date of Water Use Survey:

Number of persons in your home:

Number of pets in your home:

DOMESTIC WATER USE	TIME SPENT USING WATER	ESTIMATED LITERS OF WATER USED
Keeping Clean		
Washing hands and face		
Showering		
Taking a bath		
Taking a sponge bath		
Brushing teeth		
Preparing food		
Washing food		
Cooking		
Drinking		
Tap water		
Bottled water		
Soft drinks		
Juices		
Tea, coffee, cocoa		
Flushing the toilet		
Washing clothes by hand		
Washing clothes by machine		
Low setting		
High setting		
Washing dishes		
By hand		
In the dishwasher		
Cleaning the house		
Washing the car		
Watering the lawn		
Watering plants		
Recreation		
Wading in pools		
Playing in sprinkler		
Other uses		

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Amount of water used for your personal activities in one day: liters

Water your family uses for personal activities in one week: liters

Water your family uses for non-daily activities in one week: liters

Total amount of water your family uses in one week: liters

Reminder: Measure in liters. 1L=.26 gallons and 1 gallon=3.78 L.

What Did You Find? What Do You Think?

Compare your findings with those of your classmates and note any common patterns you find. Then answer the following questions.

1. Which domestic activities consume the most water?
2. Which uses require water of drinking quality?
3. Does your family reuse any water?
4. Can you suggest ways to use water more economically at home?
5. Think of examples of the ways water is used in your community—for example, for car washes and street cleaning. Can you suggest ways to save some of this water that won't affect quality of life?
6. Can you think of ways of using any water again for other purposes?
7. Do you think people use more water today than they did 50 years ago? Why or why not?
8. What do you think will happen if we take more and more water from our rivers, streams, and other sources?

Water Quality

1. How do your activities affect the quality of your water supplies?
2. Make a list of all the substances you and your family use that are added to water and go down the drain, such as detergents and bleach. Remember to include any fertilizer and weed killers used on the lawn. Do you think any of these substances eventually get into the ocean?
3. Discuss what you can do at home, in the yard and garden, and in leisure activities to protect the quality of your water supplies. Use reference materials to find information to support your ideas.
4. Write a short report on your findings.

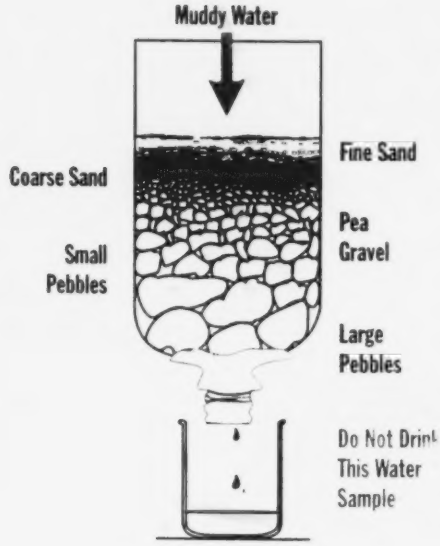
Industrial and Agricultural Use

1. How do you think water is used by industry? By agriculture?
2. Do you think any of the water used by industry or agriculture can be recycled? Write your thoughts about this and share any information that you may have gathered from reference materials.

Filtering Water

Materials

- 2-liter clear plastic soda bottle with its bottom cut off
- 5- to 7-cm square of flexible nylon screening
- Rubber band
- Large pebbles (about 150 ml)
- Small pebbles (about 200 ml)
- Pea gravel (about 150 ml)
- Coarse sand (about 600 ml)
- Fine sand (about 600 ml)
- "Swampy water": Add 0.5 liter (about 2 cups) of dirt to 4 liters of water
- Large (500-ml) beaker, or wide-mouthed jar



Procedure

1. Using the rubber band, attach the nylon screening to the mouth of the soda bottle.
2. Invert the bottle into the beaker or jar and pour the large pebbles into the bottle.
3. Add a layer of small pebbles, then layers of pea gravel, coarse sand, and fine sand.
4. Clean this filtering device by carefully pouring several liters of water through it. Try not to disturb the layers of sand. Discard the filtered water.
5. Smell and observe the "swampy water." Write a description of its characteristics.
6. Carefully pour the swampy water through the filtering device. (If the swampy water has much sediment in it, allow it to stand for a while and pour only the clearer water into the filtering device.) Collect the filtered water in the beaker or jar.

Safety Note:
DO NOT DRINK THIS WATER. In a water treatment plant, chemicals would be added to the water to kill disease-carrying organisms. These organisms remain in your water making is unsafe for drinking.

Question

Find out what kinds of filters are used in your local water filtration plant. Do they resemble this simple device?

Project Part 1: From the River to the Sea

Students investigate a river or stream in the community and find out all they can about what happens along its course. There is also an optional field trip. If the class is going to do the more extensive field survey of part of the waterway for Project Part 3, this set of charting activities may be done as research before the field survey.

This activity should be followed by "Project Part 2: Model of a Local Waterway." As an extension, you may wish to contact a surveyor, cartographer, or geologist to learn about the production and use of topographic maps.

The remaining activities in this unit are associated with Project Part 3. Integrate them as needed to suit your instructional schedule and location.

Teaching Notes

Cross-Curricular Connections: This activity integrates history, geography, and social studies and encourages students' use of multimedia references.

Materials: Provide a variety of large-scale local maps and connecting maps from your location to the Gulf of Mexico or the Atlantic or Pacific oceans. Students will need access to library or classroom references and, if possible, relevant databases.

Technological Connections

Use laser disc, CD-ROM, or other geographic databases for projection on a screen or wall.

Extensions

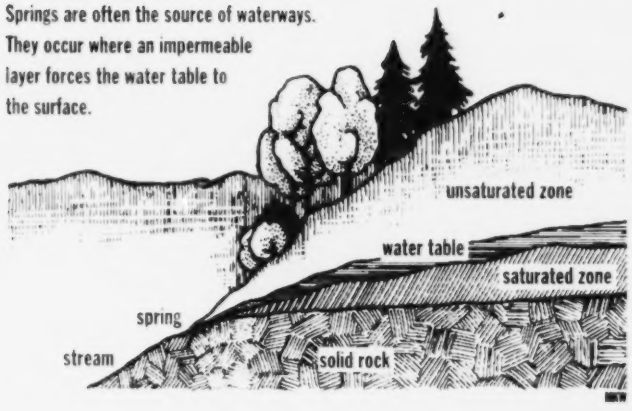
1. Encourage the students to publish their findings in a small book or journal or write an article for the school newspaper.
2. Contact local historical associations and news publications and offer to share your findings with them.

Resource

Bergman, Lincoln, and Fairwell, Kay. 1989. *River Cutters*. Berkeley, CA: Great Explorations in Math and Science, Lawrence Hall of Science, University of California.

Project Part 1: From the River to the Sea

You will select a local stream or river and trace its course from its source to its arrival at the ocean. If you live near this waterway, parts of its course may be familiar to you. Parts of the course may be visible if you drive or walk along the the water, or you may only know about the stream or river's terrain from maps.



Springs are often the source of waterways. They occur where an impermeable layer forces the water table to the surface.

You and your classmates will make three wall charts. The first will show in detail the source of the waterway and have descriptions of the animals and plants you might see if you visited there. The second will describe how the waterway affects the place you live. The third will show the waterway's whole course.

First Chart: The Source

This chart should include a detailed map of the area where the water rises. Consider the following questions:

1. Is the source high up on a hill or a mountain? What is its elevation above sea level?
2. Where does the water come from? How much rain or snow falls on the area? How does the amount of precipitation affect the stream or river?
3. Is the name of the waterway different near its source from its name when it reaches your area?
4. What kinds of mammals, birds, insects, reptiles, and plants are found in the area?
5. What is happening to the waterway in this part of its course?

Second Chart: The Local Area

Show how the waterway affects the place where you live. Sketch its route through your community.

1. Is the place where you live named after the waterway?
2. How does the waterway look today, compared to when your town or city was first established? Are there photographs or maps at a local library or museum?

Compare them with how the location looks today.

3. Did any local industries start in your area because of the water? Do you know of any mills from the days when water wheels were a major power source? Add these industries and old mills to your chart.

4. Does the water flow through (or under) the center of your community, or does it run around the edge? Have local roads or highways affected the water's course? Has the water ever been diverted from its original course? Try to find out why this happened.

5. What is the size of the local (city, town, or suburb) population? Does the local water supply come from the waterway? Do drains empty into the waterway?

6. Do local industries use the water or discharge waste products into the waterway? Put them on your chart.

7. Is there a wastewater treatment plant nearby? Where?

8. How does your area use the waterway for recreation?

9. Is there a port or harbor in the area?

10. Discuss this part of the waterway with other students in your class. Make a class report on your conclusions.

Third Chart: From Source to Ocean

Finally, prepare a large chart that shows the whole course of the waterway. You may need to consult more than one map for this. Draw your map to scale and indicate what scale you have used. Mark the distances between important locations. Put an arrow pointing north near the map on your chart.

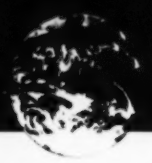
1. What is the total distance the water travels on its route to the ocean? How far do you live from where the water reaches the ocean? How far do you live from the source of the water? How did you calculate these distances?

2. What wetlands, ponds, or lakes are connected to the waterway? Does it feed a reservoir? Indicate where your waterway joins others. Add their names to your chart.

3. Mark bridges, canals, dams, and other human-made features.

4. Show cities and towns that the waterway flows through or beside. Are they named after the waterway? Are there any stories or legends associated with it? List place names with water associations, such as inns or other commercial establishments.

Course of the North Fork of the Willamette River, Oregon.



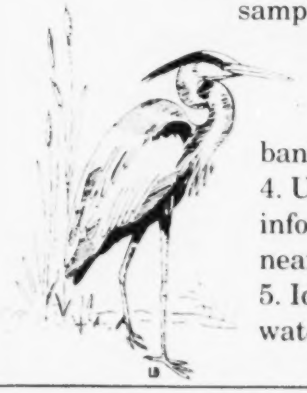
5. Are there places where farm drainage runs into the water? What kinds of animals are found on the farms or ranches near the water?
6. Are there any mines, quarries, or other operations that use water and feed waste products back into the waterway? Identify some of them.
7. Are any power plants or industries along the waterway? How do they use the water?
8. Are wastewater treatment plants along the course?
9. How do you think the waterway has been used in the past? What changes have been made to the waterway and surrounding landscape recently?
10. What can you discover about the place where the waterway flows into the ocean? Are there maps of the river mouth? Is a town or city there? A harbor for fishing boats or port for commercial ships? An estuary? A delta?

Display or Presentation

Share your findings about the history and course of the waterway with an audience. Use your charts to describe what happens to the waterway from its source to the ocean.

Optional Activity: Naturalist's Journey

If possible, visit the source or a site along your stream or river's course.
1. Take photographs, make drawings, and gather notes about what you can see there.
2. Collect a water sample from the waterway in a clean plastic soda bottle. Gather small pieces of rock from the water and banks and soil samples from the banks and bottom. Record where each sample came from.

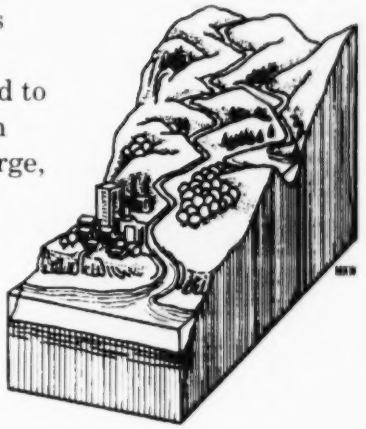


3. Do not remove plants or insects. Draw or photograph them instead. Use field guides to identify the flora and fauna you see along the banks of the waterway.
4. Use field guides to identify geological information pertinent to the course of the river near this site.
5. Identify birds and mammals that live near the waterway or visit it on their migration routes.

Project Part 2: Model of a Local Waterway

In this activity you will use homemade modeling dough to construct a relief model of your stream or river as it flows from its source to the ocean.

Prepare as many batches of modeling dough as needed to fashion a table-sized model of your local waterway. Then construct the model on a large, shallow plastic box or large, flat cardboard box lined with heavy plastic.



The Waterway Model

Create a relief model that depicts the course of the waterway, with its valleys and relief features outlined. Pay attention to the relative water levels of different parts of the course.

2. Allow the model to dry.
3. Paint the model with waterproof paint if desired.
4. When the model is complete, sprinkle a small amount of water at the head of the waterway and see if it flows to the ocean.

To Make Modeling Dough

Materials

- 110 grams (1 cup) flour
- Food coloring
- 6 grams (2 teaspoons) cream of tartar
- 240 ml (1 cup) water
- Zipper-style plastic food storage bags
- 65 grams (1/2 cup) salt
- Wooden spoon or spatula
- 30 ml (1 tablespoon) corn or other vegetable oil
- Stove or hot plate
- Metal saucepan

Procedure

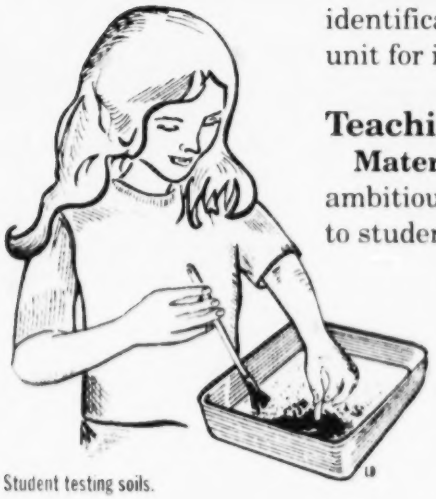
1. Mix together the flour, salt, and cream of tartar.
2. Slowly add the water, stirring, to form a uniform mixture.
3. Stir in the vegetable oil with the wooden spoon until the oil is evenly spread through the mixture.
4. Add food coloring to different batches if desired.
5. Stirring continuously, gently heat the mixture on a burner until it forms a soft ball.
6. Remove the pan from the burner and seal the modeling dough in a zipper-style plastic bag until it is needed.

Project Part 3: Survey of a Local Waterway

This activity requires a field trip to a local waterway for an extensive study focusing on water quality and local ecology. If it is not possible for the class to take a field trip, students may conclude the project instead with the activity "The Effect of Fertilizer on Classroom Mini-Ponds" on page 44.

Several other activities associated with this field survey may be done as extensions or additional projects. They are described at the end of the section.

See also the activity on aquatic invertebrate identification and water-quality evaluation from the Life unit for information relevant to this field study.



Student testing soils.

Teaching Notes

Materials and Equipment: Depending on the ambitiousness of the survey, materials that would be useful to students include dip nets, plankton nets, wire lifters, strainers, hoes, bottom scraper; stopwatches; containers for collection, such as condiment or baby food jars; white-bottomed enamel trays, clear plastic cups, dippers, eyedroppers; forceps or long-handled tongs, and tools to handle any live creatures that may be studied; microscope slides, microscopes, magnifying lenses; alcohol, masking tape for labels, waterproof markers; commercial water-quality kits, algae slides to study; algae pollution index, and various field guides. (Information is from *Environmental Science Investigations*, by Jane L. Person, 1989, J. M. LeBel Enterprises, Ltd, Dallas, TX, p. 82.)

Safety Note:
Poison Ivy and Other Hazards!
Be sure students know how to identify any poisonous plants that may grow around the waterway and any harmful snakes or snapping turtles. Students should also inform you of any allergies to insect stings.

Special Note: It is important to impress upon students that one visit can only provide an idea of what a continued study might reveal about the state of a waterway. Factors such as the season, natural fluctuations in populations of microscopic invertebrates, recent rainstorms, and the experience of the investigators will influence results. Students should therefore consider their conclusions from this survey to be only a tentative assessment of water quality.

Guidelines for a Survey of a Waterway

You may choose to divide the class into groups to correspond to the number and types of habitats surrounding the waterway. Each group can investigate a specific habitat or niche. For example, groups can study birds, the edges of the water and the ground, the bottom of the waterway, the open water, and the plants, grasses, and algae that live in and near the water.

Groups can work on water quality. Responsibilities for specific sections of the waterway can be assigned using the grid system described on page 42.

Kits and Counts

Using appropriate commercial kits, students could use a maximum-minimum thermometer to measure temperature; estimate the volume and velocity of the waterway; take coliform counts; and measure dissolved oxygen, pH, water hardness, phosphate concentration, nitrate concentration, and turbidity. Specific student handout sheets may be available with the commercial kits or in classroom laboratory manuals.

To measure the velocity of the stream, students can use an inexpensive fishing pole with line and fish floaters or make a device to deliver a cork stopper to a place in the middle of the waterway from a long pole with several eye screws and monofilament fishing line.

Guides for the Field

After assigning each group of students a specific habitat to study, provide them with field guides and identification charts. The students may make their own charts before they go into the field. They could start a field journal listing possible living things to identify with drawings and benchmarks to use in the field.

Students may conduct population studies of the macroinvertebrates that live in the water and describe where they are found. Specimens may include copepods, crayfish, flatworms, hydra, jellyfish, leeches, mussels, snails, scuds, seed shrimp, tubifex worms, water fleas, water mites; caddis fly, crane fly, and midge larvae; dragonfly, damselfly, mayfly, and stonefly nymphs;

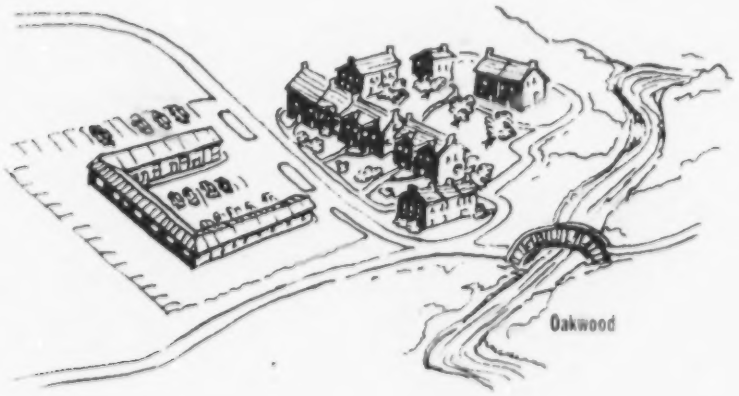
backswimmers, diving beetles, whirligig beetles, scavenger beetles, water boatman, water scorpion, water striders, and mosquitoes.

Technological Connections

If students have access to computer software and suitable application programs, they may wish to put together a computer-generated report of their survey of the water site.

Extensions

1. "The Effect of Fertilizer on Classroom Mini-Ponds" (page 44). You may prefer to do this activity before the field study or use it in place of the field study.
2. "Restoring the Runnins River" (page 47). In this case study, Nynex award winners describe their experiences tackling pollution problems in their local river. Your students may choose to do a more ambitious study of the local waterway to determine the state of water quality through continued monitoring and investigation, surveys, research, and other methods. Students may also discover threats to the local ecology and propose creative solutions to any problems.
3. "The Clean Water Challenge" (see Challenge unit). In this role-play activity, students conduct an investigation of a mysterious pollution incident and in the process identify all of the possible sources of water pollution in a fictional town.



Resources

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Project Part 3: Survey of a Local Waterway

What do we mean when we say that water is polluted? Today, we frequently learn about water pollution through the media. We hear people talking about polluted water.

Is pollution simply a matter of the water being dirty, smelling bad, or being a strange color? Or is water polluted when people cannot use it for drinking or for other domestic and commercial purposes?

Is polluted water safe for animals, insects, and plants? Or is water polluted when animals, birds, and fish cannot drink it or live in it?

How do you describe water pollution? Write your ideas down and compare them to your classmates ideas.

A Freshwater Quality Survey

In this field activity, you will visit a local site and investigate its ecology and water quality. This site may be part of the same stream or river that you studied in Project Parts 1 and 2, or it may be a nearby canal, pond, or marsh.

Pond with Cattails

The following questions will direct your initial investigation. Your teacher will assign more specific duties and may divide the class into groups.

What Kind of Site Is It? Start by observing the site and taking notes about what you see. Look over the questions from the sample report to get some ideas about the important features of the water.

- Write a brief description of the area.
- Draw or photograph the site's main features.
- Prepare a sketch map of the environment using the grid on page 42 as a base for your map.

How Is the Water Used? Make a list of all the ways the water at the site is used. If it is a stream or river, try to take into account what happens to the water upstream and downstream from your survey site. Include uses like swimming, boating, and fishing, but remember that people are not the only ones who use the water.

To investigate water pollution, you will need to decide if the water quality is suitable for the uses to which it is put. Make a table similar to the one that follows.

Some General Questions for Your Report

Here are some questions your class will consider for your water-quality report:

- What color is the water?
- What does the water smell like?

- Where does the water come from?
- Where does the water go?

- How deep is the waterway?
- What is the distance across it?
- What temperature is the water?
- How fast is the water moving?

- Do you see any green slime? Estimate how much there is.
- Do you see any brown slime? Estimate how much there is.

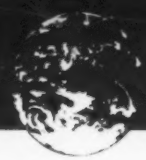
- Are there plants growing in the water? List the plants that you recognize and write descriptions of others so you can identify them later using the class's field guides. Use the grid system described below to record the location of the plants that you see.

- Are there animals in or near the water? Identify the organisms you can see. Use the same grid system to count these organisms and locate their habitats in the waterway. Bring back a sample of water so you can use the microscope to look for microorganisms.

- Are there any signs of scum, froth, or oil in the water or on the banks? Can you tell where it is coming from?
- Is there any rubbish in the area? Identify the types of rubbish and estimate how much of each type is present.

- Which fish are living in the water? Where did you get your information?
- Are there birds at or near the site? Identify them. Describe how they use the waterway.
- Are reptiles living at the site? Try to identify them. Describe how they use the site.

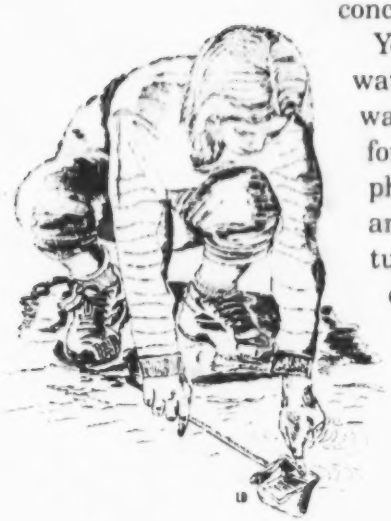
- Are there signs of vandalism?



An In-Depth Investigation

You and your classmates may be assigned to groups to survey a small section of the waterway so that your combined data will give a more complete picture of the ecology of the waterway. Or individual groups may concentrate on a particular niche or habitat.

Your teacher may ask you to do chemical and biological water-quality tests and bring back small samples of water to test in the classroom. Test kits are available for toxins damaging to fish and plant life, water pH, phosphates, nitrates, ammonium, bacterial pollution, and dissolved oxygen. While in the field, you may do turbidity tests or other tests for environmental contamination. Your teacher will instruct you in the correct and safe use of these tests and supervise your field collecting.



Student uses scoop net to collect invertebrates from near rocks in stream.

Some Measurements

Work with your teacher and group to use tools available to you to take measurements at the site.

1. Throw large balls of twine or fishing line across the water, then measure the length of the twine to get the dimensions of your site.
2. Drop string with attached sinkers and measure the amount of string under water to measure the depth of the water site at various locations.
3. Place a fishing lure attached to a rod in the stream and allow the current to carry the lure downstream for a measured time period to calculate the average velocity of the water.

A Sample Report

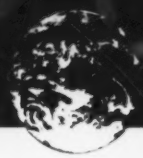
DATE OF WATER SURVEY:

LOCATION:

TYPE OF WATER AREA:

USES: ❑ Swimming ❑ Boating ❑ Fishing ❑ Farm Drainage ❑ Sewage Disposal

QUALITY QUESTIONS	DESCRIPTIVE NOTES
WHAT COLOR IS THE WATER?	
WHAT DOES IT SMELL LIKE?	
WHAT TEMPERATURE IS IT? How did you measure temperature?	
HOW DEEP IS IT? How did you measure depth?	
IS THE WATER MOVING? HOW FAST IS THE WATER MOVING? How did you measure velocity?	
WHERE DOES THE WATER COME FROM?	
WHERE DOES THE WATER GO?	
ARE PLANTS GROWING IN THE WATER? List plants that you recognize and write descriptions of others so you can identify them later using field guides.	



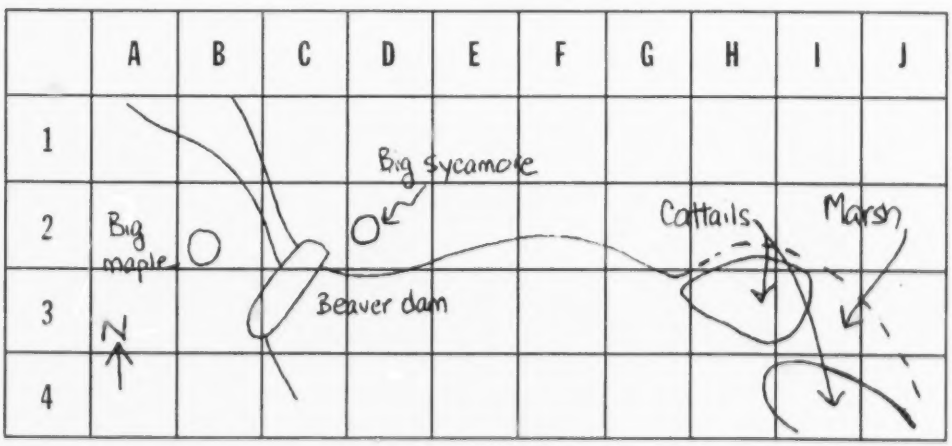
A Grid System

1. Use a grid as a reference to keep track of the original location of water samples, plants, and organisms.
2. For the field survey, start by sketching the water site on a grid. Use a scale and indicate directions (North, South, East, West).
3. After the physical characteristics of the water site are drawn, label the rows with numbers and the columns with letters, as on a road map, so the items taken from each section can be identified.

Example of a Grid System

	A	B	C	D	E	F	G	H	I	J
1										
2										
3										
4										

Grid with a map



The Survey Report

Together, the class will make a table that shows the information you have gathered for your water-quality report, including all of your descriptive notes and the water uses you have identified. Use large pieces of posterboard, because there is probably a lot of information to be recorded.

Assign a separate column to each of the water uses. Use your own words for column headings. Create a color code to indicate the suitability of the water at your site for the various uses, and put the appropriate colored symbol in each box.

If you studied the same site for the previous activities, add this report to the charts that you made for Project Part 1, when tracing the waterway, and place them near the relief model of your waterway from Project Part 2.

Example of a Suitability Color Code

If you decide that a feature (like color, temperature, plant growth, bird population) makes the water:

Desirable for the particular use, put a green check mark in the space.

Acceptable for the particular use, put a blue dot in the space.

Undesirable but not unfit, put an orange dash in the space.

Unfit for the use, put a red X in the space.

If the feature is not relevant, leave the space blank.

Desirable = ✓ Acceptable = • Undesirable = — Unfit = ✗

The Effect of Fertilizer on Classroom Mini-Ponds

Materials

- 10 or more 2- or 5-gallon (about 7.5- or 19 L) aquariums or 2-gallon (about 7.5 L) glass pickle or mayonnaise jars (available from commercial food services).
(Reminder: 1 gallon = 3.78 liters.)
- Water from a local pond or stream
- Tap water
- Funnels, stirring rods, and graduated cylinders
- 8-24-8 uncolored garden fertilizer
- pH paper
- Water test kits for nitrates and phosphates
- Dissolved-oxygen test kits (optional)
- Microscopes

Look through the water in the pond to read the following message.

CLEAR	The print is easy to read
SLIGHTLY CLOUDY	The print is fuzzy
CLOUDY	The print can be seen but not read
VERY CLOUDY	The print can barely be seen
OPAQUE	The print cannot be seen

Turbidity Identification Card

Procedure

1. Number and fill 10 identical containers with 1.5 gallons of tap water each (or 4.5 gallons each if you are using the larger aquariums) and either allow them to sit in a sunny place for several days to eliminate most of the chlorine gas or treat them equally with aquarium chemicals to remove chlorine. Reserve the tenth container so you will have a continuous supply of chlorine-free water.

2. Create model pond environments in nine of the containers by adding 150 to 200 ml of the local water to each. The original water levels in each of the nine containers should be the same, and the same amount of local water should be added to each container.

3. Make a solution of a plant fertilizer (such as 8-24-8) using chlorine-free water. Add 4 tablespoons of fertilizer to 4 liters of water. This will be the stock solution. Keep it in a labeled glass jar with a tight cover.

4. Add fertilizer solution to the model pond jars as follows: Pond 1: 2 ml; Pond 2: 4 ml; Pond 3: 6 ml; Pond 4: 8 ml; Pond 5: 10 ml; Pond 6: 12 ml; Pond 7: 14 ml; Pond 8: 16 ml. Pond 9 gets no fertilizer solution; this pond is the control. Reserve the 10th jar of chlorine-free water to replenish water that evaporates from the ponds.

Now add water from the reserve jar to the model pond

jars as follows, so each pond will have the same amount of liquid at the beginning of the investigation: Pond 1: 14 ml; Pond 2: 12 ml; Pond 3: 10 ml; Pond 4: 8 ml; Pond 5: 6 ml; Pond 6: 4 ml; Pond 7: 2 ml; Ponds 8: no additional water; Pond 9: 16 ml.

5. You may wish to make data tables similar to the ones shown on the next page to record your observations and information.

6. Make a clearness or turbidity identification card like the one shown on the previous page.

7. At the same time every day, look through each pond towards the light and describe what you see. Note the color of the pond. Is it clear, gray, green, blue, or brown? Colorless, with particles suspended in it? Yellow or tan?

8. When you check for color and intensity, also check for turbidity. Look through the pond at the turbidity identification card and record your observations.

9. As soon as you have checked for color and turbidity, remove small samples from each pond with medicine droppers. Test these samples for phosphate and nitrate concentrations. Record the results of the tests. You may also wish to test for pH and dissolved oxygen every day.

Pond	ml of 8–24–8 fertilizer solution	ml of chlorine-free water
1	2	14
2	4	12
3	6	10
4	8	8
5	10	6
6	12	4
7	14	2
8	16	0
9	0	16

10. To look for organisms that live in the ponds, take additional samples and examine them in white porcelain trays. You can also use the microscopes to identify organisms living in the ponds.

Estimate the number and type of organisms found living in the ponds. (How will you do this? Think of the amount of liquid that you take out of the pond for the test as a portion of the liquid in the pond. Use this ratio to find a factor that you can multiply the number of organisms by to estimate the total number present in the pond.)

ACTIVITY SHEET : WATER PROJECT PART 3

Observations and Conclusions

After two weeks, write a report describing your observations and ideas about what you found. Consider the following questions:

1. What happened to the color of the model ponds?
2. Which pond had the most intense color?
3. Which pond was the clearest? The most turbid?
4. Which pond had the greatest number of organisms?
5. Which pond had the greatest variety of organisms?
6. Which pond had the best nutrient level for a healthy ecosystem?
7. How did the increase in amount of added fertilizer affect the organisms in the ponds?
8. How did the increase in amount of added fertilizer affect the growth of algae in the ponds?
9. Would you classify any of the ponds as polluted? If so, which ones? Why?
10. Describe what you mean by a polluted pond.

Pond Background Sheet

Pond	Initial amount of Water	ml of Fertilizer Solution Added	ml of Chlorine-Free Water Added
1			
2			
3			

Tests and Observations (Make one table for each day of observation.)

Date of Observation _____ Time of Observation _____

Pond	Color and Intensity	Turbidity	Phosphate Concentration	Nitrate Concentration	pH Value
1					
2					
3					

Organisms Observed (Make one table for each day of observation.)

Date of Observation _____ Time of Observation _____

Pond	Type of Organism	Number Observed	Algae Type	Amount of Algae Present
1				
2				

Restoring the Runnins River (Excerpted and Adapted)

Alison McLennan, Aimee Olin, Lillian Shuey, and Christopher Gordon

This case study is an excerpt of a summary written by the first-place winners of the 1993–94 NYNEX Science and Technology Award. The four team members were students at Wheeler School, Providence, RI. The teacher/advisor for the project was Robert Brown.

The NYNEX competition is administered by the National Science Teachers Association. Prizes include scholarships for all finalists and grants that enable the top three teams to put their ideas into practice.

We are a group of four students who enjoyed our environmental science class in ninth grade and went on to identify a local problem involving the water quality of the Runnins River. These last two years, we have been working on a practical "solution to the pollution."

Using advanced field techniques to test various aspects of the river's health, we have formed a general conclusion: the fecal coliform level is much too high, while the dissolved oxygen (D.O.) level is too low. For the fecal coliform, this is especially true during and following rainstorms, and the mouth of the river must be closed to shell fishing.The low dissolved oxygen is a chronic problem, and will not sustain a balanced ecosystem. In addition, toxins from highways which cross the river make it impossible to support biological life for any length of time.

Over the past two years, we have done extensive monitoring of a section of the river. This included performing dissolved oxygen, pH, temperature, and fecal coliform tests, and the collection of Benthic macroinvertebrates. The results of our testing allowed us to pinpoint specific pollution sources within the mile of the river we are focusing on.

The dissolved oxygen test determines how many milligrams of oxygen are in a liter of water. From the results of our testing, we pinpointed some pollution problems within this section of the river. At one site, we found an exceptionally low D.O. as a consequence of a chain reaction beginning with fertilizers leaking off a golf course into a stream. As a result, the bacteria population explodes, using up dissolved oxygen. Algae eat the nutrients, therefore an algae bloom is created, whose composition uses up more dissolved oxygen.

Dissolved oxygen is affected by the temperature of the water. Shallow water is more likely to be warmed by the sun, making the levels lower. We wanted to know whether the Grist Mill pond, at the end of our section, is a shallow pond. This would help to explain the D.O. level.

We took two canoes to the pond and tied lines across the pond at 20-foot intervals. Each line had a knot every 20 feet, where we measured the depth, turbidity, and water temperature. We also measured the pH level and D.O. at three points in the pond. The results showed that the pond was indeed shallow, six feet maximum, and about 50 percent was six inches or shallower. The pH levels and D.O. levels were insufficient to support most large aquatic species.

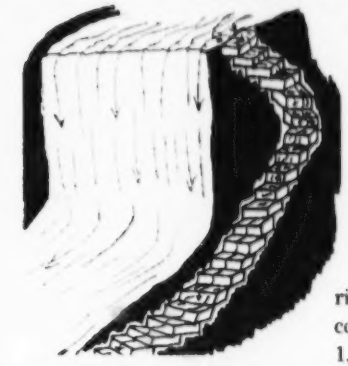
To raise the D.O. level in this portion of the river we propose installing fountains or other aeration systems. A fountain would fully aerate the pond, reduce the sediment and the nutrients, and add aesthetic beauty. In a fountain, the water is shot into the air, so the air mixes with the water. Then the air-filled droplets return to the pond and distribute more dissolved oxygen into the water.

Fecal coliform is found in the waste of warm-blooded animals. A high level signifies a large amount of waste in water. Because waste carries disease, the more fecal coliform present, the greater the chance that human disease is there as well.

The procedure we used for measuring the fecal coliform levels in the river was the Millipore Membrane Filtration Technique. This technique involved taking a sample of water, sucking it through a filter using a vacuum, and then placing that filter paper in a petri dish, with a nutrient, in an incubator overnight. Fecal coliform was measured in number of colonies per 100 milliliters of water. Public health officials take this seriously; recently a nearby town was thrown into a

Adapted from "Restoring the Runnins River," *The 21st Century*, June 1994, 20–21.

ACTIVITY SHEET : WATER PROJECT PART 3

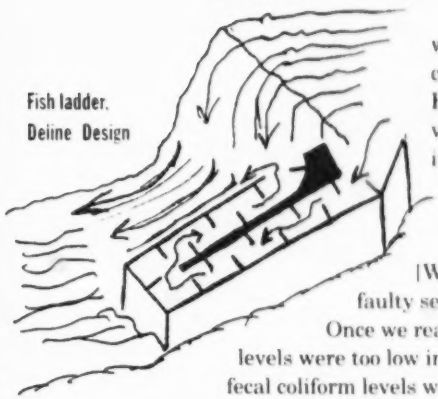


Fish ladder, Bar Harbor Design

water crisis because a count was found in the single digits. When we found fecal coliform in the thousands, we realized the river was a public health threat.

As a result of our fecal coliform tests, we traced pollution of the river to one particular neighborhood built 10 years ago as a development. We found two storm drain pipes leading right into the river with fecal coliform levels of 3,620 and 1,140.

Last year our group did a fair amount of community outreach. We began by sending a newsletter out to all the people in the river neighborhood. This newsletter explained who we are and what we were doing. Then we conducted a phone survey that asked the residents about septic and lawn maintenance. Our third step was to hold a community meeting, so we could inform the community of our river work and results.



Fish ladder, Deiine Design

The last measure was to bring our health concerns to the Board of Health. They helped to validate our information and were truly concerned that our fecal coliform levels were so high. [We proposed rebuilding faulty septic systems.]

Once we realized that the D.O. levels were too low in certain areas and the fecal coliform levels were too high in others, our next action was to see what kind of biological life was living at these sites. We collected several samples of Benthic macroinvertebrates over a two-year period. Benthic macroinvertebrates are insects that live on the bottom of the river.

A macroinvertebrate habitat consists of a shallow area with a rock bottom where the water runs rapidly. In order to collect the insects from their habitat, we used the kick net method, which consists of scrubbing the rocks in an 18 by 18 inch area on the river bottom for two minutes upstream of a net, so all of the material scrubbed off ends up in the net.

We concluded that because of the low dissolved oxygen rates caused by fertilizers and sewage, the stream cannot support the amount of biological life that a high water quality stream can.

Solving the problems with the D.O. and nutrient levels would allow the stream to serve as an adequate fish habitat. There is still one problem that would prevent the fish from inhabiting the river: two large dams and waterfalls that fish are unable to swim up. We propose constructing fish ladders at both sites, so the fish are able to swim up the river to spawn. This would also, hopefully, restore the old shad run to the Runnins River.

To understand the problem of the shad, you first must understand their habits. The adult shad return to the river where they were born and swim upstream to an area to spawn. They then return to the sea and will return to the river as many as five or six times in their lifetime. While the adults are returning to the sea, the eggs drift down the river until they hatch, days later. The infant shad must swim back up the river until they find a slow-moving pool or pond in which to spend the summer. Later in the fall, they go back down the river to the sea, where they stay until they are three to four years old. Then they return to the river to spawn, starting the cycle again. Without the slow-moving water, they die. For the last 10 years this has been happening, so the shad run is now all but gone.

This problem may be solved by installing fish ladders on the two Runnins River dams. These ladders would give the infant shad a way to get to a pond during the summer. The fish ladders will not only be used by migrating shad, but by other aquatic animals as well. Sport fishing would return to this portion of the river for the first time in over a decade.

In conclusion, our team has hope for the future of the Runnins River. We would like to spread this attitude throughout the community, so the river's water quality can be restored. This accomplishment will in turn inspire us and others to be committed to the well-being of the river.

The Composition of Water

In this activity, the students observe the decomposition of water through electrolysis by passing a direct current through water and collecting the products to be tested for identification.

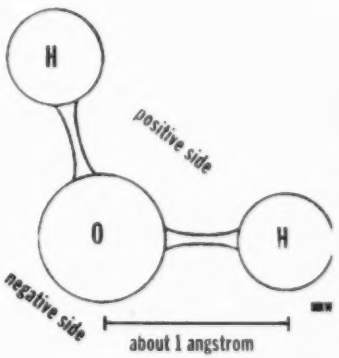
Physical and Chemical Change

The decomposition of water is a good concept for students to study. Often they confuse the electrolysis of water with the boiling of water, not understanding the difference between change of state, a physical change, and decomposition, a chemical change.

You may wish to emphasize that two of the major steps of the water cycle involve physical changes (condensation and evaporation) while pollutants that enter water may react chemically with it.

The Water Molecule

Many of the unique properties of water as a solvent are due to the chemical composition and make-up of water. Water consists of two atoms of hydrogen bonded to one oxygen atom in a polar molecule that exhibits both a positive and a negative charge. (This activity may also be used to illustrate that atoms combine in whole-number ratios to form molecules. Oxygen and hydrogen as gases are diatomic molecules, so the electrolysis reaction equation is $2H_2O = 2H_2 + O_2$. Students will see twice as much hydrogen as oxygen.)



The water molecule

Testing for Hydrogen and Oxygen

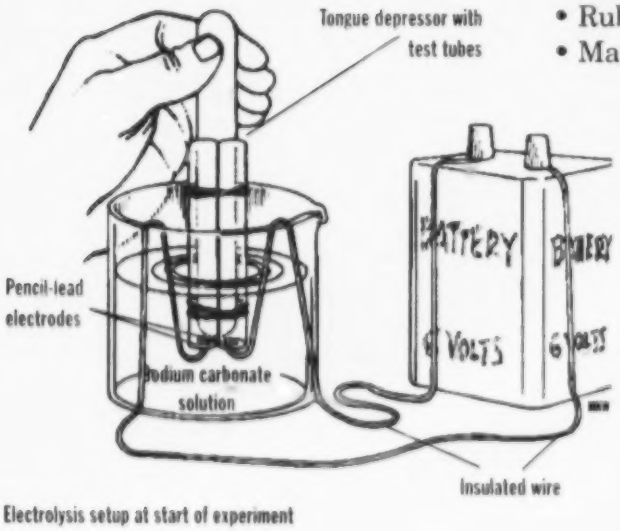
If your students are familiar with the splint test for hydrogen gas and oxygen gas, let them test the products of the electrolysis.

By testing the products of the electrolysis, students will see that molecules of water differ both physically and chemically from their constituents, atoms of hydrogen and oxygen.

The Composition of Water

Materials

- A 6-volt battery
- A 30-cm ruler
- Tongue depressor
- Rubber band
- Matches
- Safety goggles and aprons
- 2 wooden splints
- 2 10x75 mm test tubes
- 2 pencil leads (graphite), cut out from the inside of #2 pencils; the teacher should prepare these
- A 400-ml beaker or large, wide-mouth glass jar
- A 1-m length of #18 insulated wire
- A 20-cm length of insulated wrapping wire
- 2 pieces of electrical tape, about 10 cm in length
- 2 alligator clips or fasteners for the 6-volt battery
- 10 g (2 tsp) sodium carbonate (washing soda)



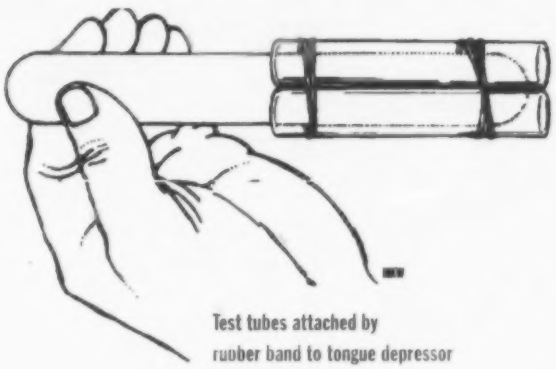
Electrolysis setup at start of experiment

Procedure

1. Cut the 1-meter length of wire in half and strip 2 to 4 cm of insulation from each end.
2. Attach one stripped end of one wire to a piece of pencil lead by wrapping the wire and lead tightly with wrapping wire. Attach the other wire and pencil lead in the same manner.
3. Carefully wrap these connections with electrical tape, so no copper wire remains exposed.
4. Attach the alligator clips to the other ends of the long wires or make small loops for the battery attachments.
5. Set these two pencil-lead "electrodes" aside.
6. Add sodium carbonate to 300 ml of tap water in a beaker, stir, and allow it to dissolve. (Because sodium carbonate breaks up into charged particles in water, a solution of sodium carbonate is a better conductor of electrical current than plain tap water.)

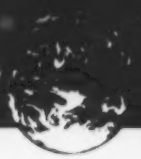
7. Place the tongue depressor on the table and lay the two test tubes side by side on top of it, so the mouths of the test tubes are lined up at one end of the tongue depressor.
8. Fasten the test tubes to the tongue depressor with a rubber band. The tongue depressor will serve as a handle for the test tubes.
9. Fill the test tubes by immersing them in the sodium-carbonate solution.
10. Holding the test tubes by the handle, and covering the mouths of the test tubes with your fingers, invert the test tubes into the solution in the beaker.
11. Insert one pencil-lead "electrode" inside each inverted test tube, so the electrodes are just inside and near the mouths of the inverted test tubes. Be careful not to let any air get into the inverted test tubes.
12. While one member of your group continues to hold the tongue depressor with inverted test tubes and electrodes in the sodium-carbonate solution, discuss what you think will happen when the wires from the electrodes are attached to the battery.

Safety Notes:
Students and teachers must wear safety goggles and aprons. Teachers will need to extract the pencil leads. One way is to use a single-edge razor blade or small sharp knife. Remove the eraser and metal collar and push down along pencil seam.



Test tubes attached by rubber band to tongue depressor

13. Make a prediction about what will happen, and explain why you think this will happen.
14. Connect the electrodes to the battery.
15. Record your observations.
16. Compare your observations with your group's predictions.
17. After several minutes have passed, look for evidence that a gas is forming at each electrode.
- Is the liquid in each test tube being displaced by a gas?
- Are there equal amounts of gas forming in the test tubes? If not, measure the height of the column of gas in each test



tube with the ruler. Record your data.
18. Discuss with your group what you see happening. Why do you think there is more gas in one test tube than the other?
19. When one of the test tubes is nearly filled with gas, hold the test tubes and gently remove the rubber band and tongue depressor. Be careful to keep the mouths of the test tubes inverted in the sodium carbonate solution.
20. Still holding the test tubes upside down, take the test tube that is filled with gas out of the beaker.
21. Still holding the test tube upside down, put a BURNING splint to the lip of the tube. Record what happens.
22. Remove the second test tube from the beaker and place it in an upright position.
23. Insert a GLOWING splint into the upright test tube. Record what happens.

Analysis

1. From your observations of the behavior of these two gases, can you make a prediction about their identities?
2.What was the ratio of the volume of gas in one test tube to the volume in the other? (Compare the heights of the columns of gases that you measured earlier.)
3. Why do you think there was twice as much gas in one test tube as in the other?
4. What does the ratio of the gases' volumes indicate about the composition of water?
5. Describe in words what you think happens when a direct current passes through a solution of water.

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